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SURFACE WATER SECTION

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Illinois Department of
Energy and Natural Resources

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SEDIMENTATION OF POOL 19 ON THE MISSISSIPPI RIVER NEAR HAMILTON, ILLINOIS: BACKGROUND ANALYSIS

by

Nani G. Bhowmik and J. Rodger Adams



Champaign, Illinois
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SEDIMENTATION OF POOL 19 ON THE MISSISSIPPI RIVER
NEAR HAMILTON, ILLINOIS:
BACKGROUND ANALYSIS

by Nani G. Bhowmik and J. Rodger Adams

Introduction

Streams and rivers are dynamic systems in which erosion and sedimentation take place on a continuous basis. When the inflow of sediment exceeds the normal carrying capacity of the river, sedimentation will occur. The river will then become shallower with a fairly well defined main channel or will behave like a distributary channel without any defined channel. Natural and man-made constrictions can either accelerate or prolong the normal transition of rivers from one hydraulic state to another.

The city of Hamilton, Illinois, is located on the east bank of the Mississippi River near Lock and Dam 19 (figure 1). The city is dependent on the Mississippi River for its water supply, and it also maintains public access to the river from its park system located on the east bank of the river just upstream of Lock and Dam 19. Excessive sedimentation over the years has virtually choked the city's water intake and has made it almost impossible for its citizens to enter the main channel of the river from its public docking facilities near the mouth of Cheney Creek. The city is now contemplating asking the U.S. Army Corps of Engineers to consider keeping some of the gates on Lock and Dam 19 near the east bank of the river open, with the hope that increased flow near the east bank would scour and transport some of the deposited sediment from upstream of the dam in the downstream direction. This increased scouring might help to maintain a deep channel near the east bank of the river, which is essential for recreational access to the river by the local communities.

After a discussion with the Office of the Mayor of Hamilton, Illinois, representatives of the Department of Conservation, and other interested public officials, it was decided that a background report outlining the available information on the sedimentation patterns upstream of Lock and Dam 19 would be extremely useful for the development of a management alternative for this reach of the river. Also it was felt that

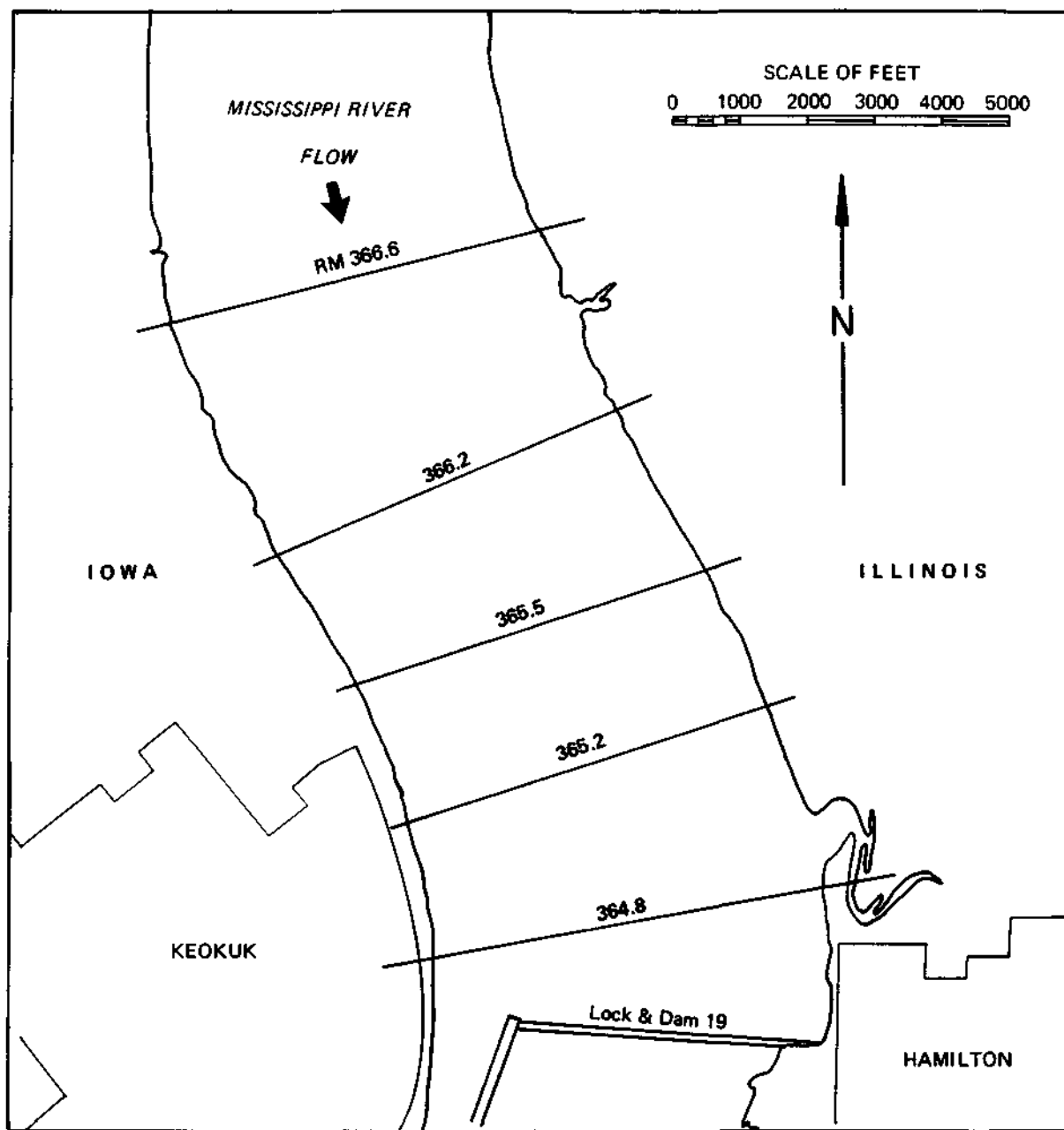


Figure 1. Lower portion of Pool 19 on the Mississippi River

if a demonstration project such as this one is initiated, in which some of the gates are kept open to scour and move the sediment, then a scientific and engineering evaluation must be made. Such an evaluation would determine if such an alternative is feasible and how these results could be used on a semi-permanent basis not only for Pool 19 but also for other similar areas along the Mississippi, Illinois, and many other rivers with dams in Illinois. This report has been prepared to address these and other related topics.

Background

Pool 19 extends from Keokuk, Iowa, past Burlington, Iowa, for a distance of 74.5 km. Lock and Dam 19, constructed in 1913 to facilitate navigation past the Des Moines Rapids, is the oldest and highest lock and dam (11.6 m) along the river. Pool 19 is the longest pool of the entire navigation channel. At the flat pool elevation, the head on the dam is 11.64 m, which is the highest head differential on the Mississippi River except for that at the Upper St. Anthony Falls lock, which has substandard width. This lock and dam also includes a hydroelectric power plant. The tailwater level fluctuations are limited to a maximum daily value of 0.6 m, and the gates are operated to maintain a nearly constant level above the dam.

Figure 2 is a plan view of Pool 19, including most of the tributary streams. At normal pool level of 157.95 m above sea level, the surface area of the navigation channel is about 9 million m², and there are another 116 million m² of water outside the navigation channel (U.S. Army Corps of Engineers, 1981). The average slope of the thalweg is about 0.076 mkm⁻¹. The depth to bedrock in the river valley varies from 4 to 48 meters. Deposits from glacial action raised the river bottom by about 30 meters above the pre-glacial elevation. The upstream part of the pool has 11-km-wide floodplains which are protected by levees. The narrowest section of the floodplain near Nauvoo (figure 2) is about 3 km wide.

The mean annual precipitation on the Pool 19 drainage area is about 0.82 m and the average temperature is about 11 C. The mean annual runoff of the river at Lock and Dam 19 is about 18 mm. The channel is maintained at a minimum dredged width of 122 meters, and the navigation depths vary from 2.75 m near the upper reaches to 11 m near Lock and Dam 19. The

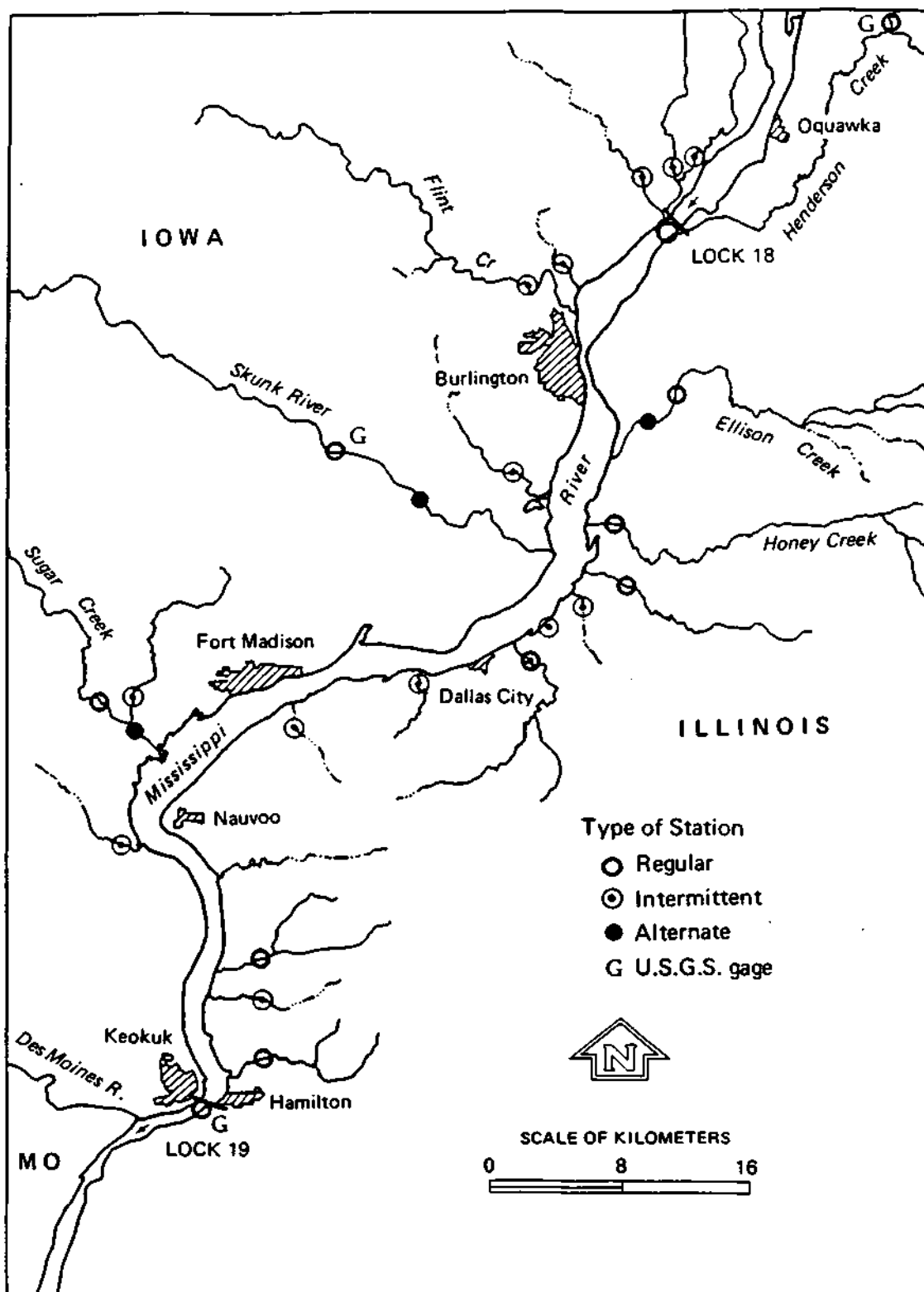


Figure 2. Plan view of Pool 19

drainage area at Lock and Dam 18 is about 294,200 km². The tributary drainage area from Lock and Dam 18 to Lock and Dam 19 is about 14,000 km², of which 80% is contributed by the Skunk River and 11% by Henderson Creek. The power plant is a run-of-the-river facility, and a negligible quantity of water can be stored in Pool 19 for flood control.

Water Flows: The discharge record for the Mississippi River at Keokuk begins in 1878 (figure 3). The mean annual discharge for 102 years is $1,774 \text{ m}^3\text{s}^{-1}$ ³⁻¹. The maximum daily flow during the 1973 flood was 9,740 m³s⁻¹ and the minimum daily low flow was 142 m³s⁻¹ in 1933. For the 20 years prior to construction of the dam, the minimum flow was 566 m³s⁻¹ and the maximum was 10,550 m³s⁻¹. The Skunk River contributes 77% of the tributary inflow to Pool 19. Henderson Creek and Skunk River together contribute 90% of local inflow and have a significant impact on the environment of the pool.

Sediment Transport: Instream sediment transport data from the Mississippi River at Keokuk have been collected since 1968 by the Rock Island District, U.S. Army Corps of Engineers. Similar data for the Skunk River at Augusta and Henderson Creek near Oquawka have been collected since 1975 and 1978, respectively. Data from 22 tributary streams were collected during the 1982 calendar year, and the Water Survey is continuing to monitor 6 streams (Bhowmik and Adams, 1986). Moreover, three sedimentation surveys of Pool 19 have been conducted since 1913 (Thomas, 1977).

Suspended sediment data have also been collected at Burlington, Iowa, on the Mississippi River. With the aid of the two sets of data for the Mississippi River, a preliminary sediment budget for this pool has been determined. Figure 4 shows the average annual sediment transport rates at Burlington and Keokuk from 1968 through 1979. If it is assumed that differences between the sediment loads at Burlington and Keokuk indicate net deposition or scour of the pool, Pool 19 has been experiencing a gradual loss of capacity due to sedimentation. On the average, about 11,866 million kg of sediment are depositing annually within this pool. It was also observed that, for the same period, the maximum sediment transport rates were 28,698 million kg at Keokuk in 1973 and 22,170 million kg at Burlington in 1974.

The low flow period of 1977 had a significant impact on the sediment movement in this pool. From figure 4, it is clear that the sediment

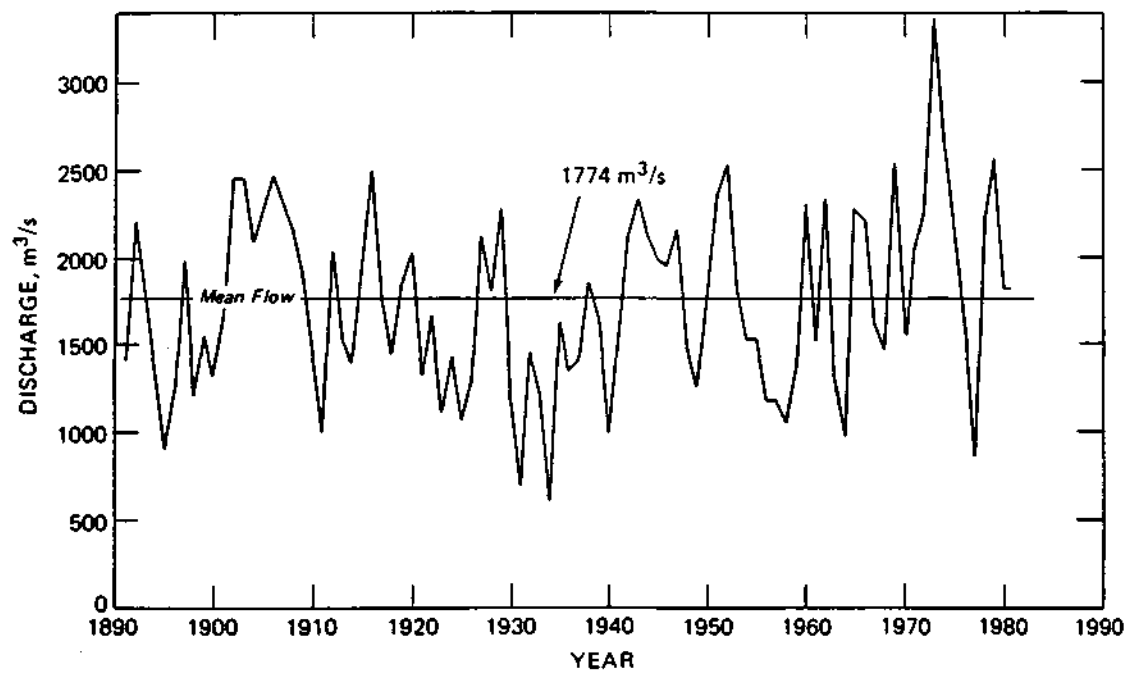


Figure 3. ^r Discharge variability of the Mississippi River at Keokuk

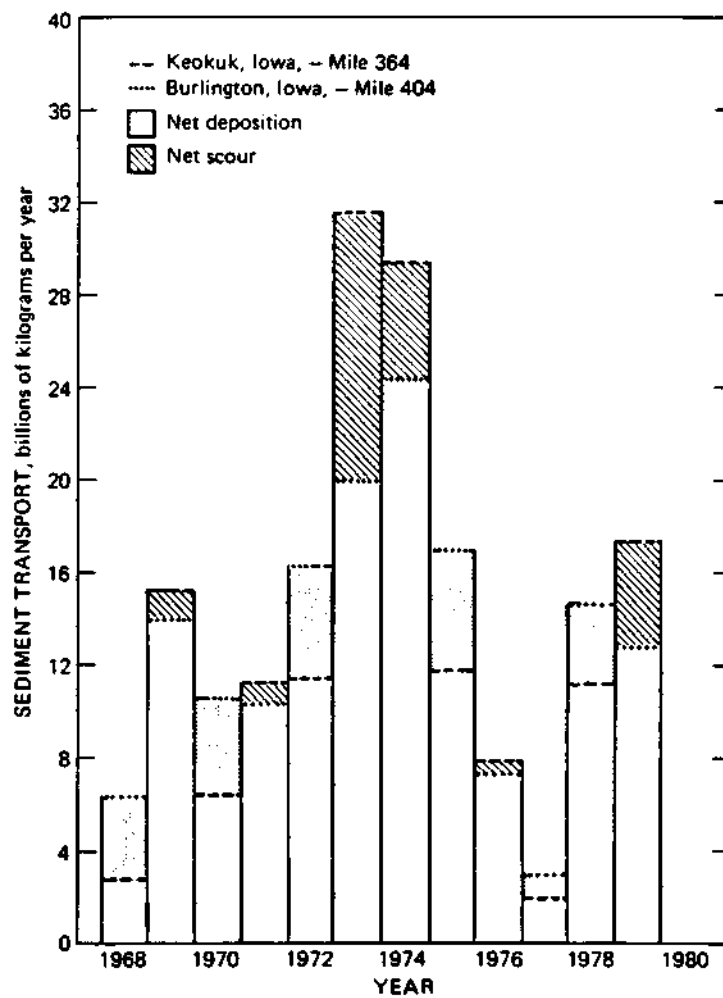


Figure 4. Annual suspended sediment transport of the Mississippi River, Burlington and Keokuk gaging stations

transport rates were lowest in 1977: 2,680 million kg at Burlington and 887 million kg at Keokuk.

The maximum deposition occurred in 1972, when 4,791 million kg of sediment were deposited within the pool. The maximum scour occurred in 1973, when 10,595 million kg of sediment were eroded and transported downstream out of the pool.

Sedimentation: Lock and Dam 19 was completed and began to impound water in 1913. Before the construction of this structure, the Mississippi was a free-flowing natural river. As with any impoundment, as soon as the dam began storing water, it also initiated deposition of suspended sediment load within the pool. In the previous subsection, it was shown that after 70 years, sediment is still being deposited in Pool 19.

Figure 5 shows the decreasing pool volume from 1913 to 1979. The volumes of the pool in 1928, 1938, and 1946 were determined from sedimentation surveys in those years (Thomas, 1977). The change in volume from 1968 to 1979 was calculated by using the sediment budget from the preceding section. The change in volume between 1946 and 1968 was estimated from the average of the sedimentation rates for the periods 1938-1946 and 1968-1979. In 66 years, 55% of the original volume of Pool 19 filled with sediment. This is an average loss of 0.83% of the original volume per year. The highest capacity loss rate occurred between 1913 and 1928, with a decrease in rate of sedimentation thereafter.

The highest sedimentation rates within the pool have been observed on the Illinois side just upstream of Lock and Dam 19 (see figures 1 and 2). The lock is located on the Iowa shore near Keokuk, and the navigation channel is close to the Iowa shore. The release of water through the turbines and the lock prevents sediment deposition near the Iowa shore. However, since most of the gates are closed for much of the year, the water upstream of the dam near the Illinois shore remains almost stagnant, increasing the sediment deposition rate at this location. From the plot of a cross section just upstream of the dam (figure 6), it seems probable that about 60% of the width of the river from the Illinois shore has reached an elevation that will not change significantly with time. The sedimentation rate at this location has been about 44 mm/yr since 1946.

This sand bar or impending island formation extends for about 3 to 5 km upstream of the dam. The navigation channel shifts toward the Illinois

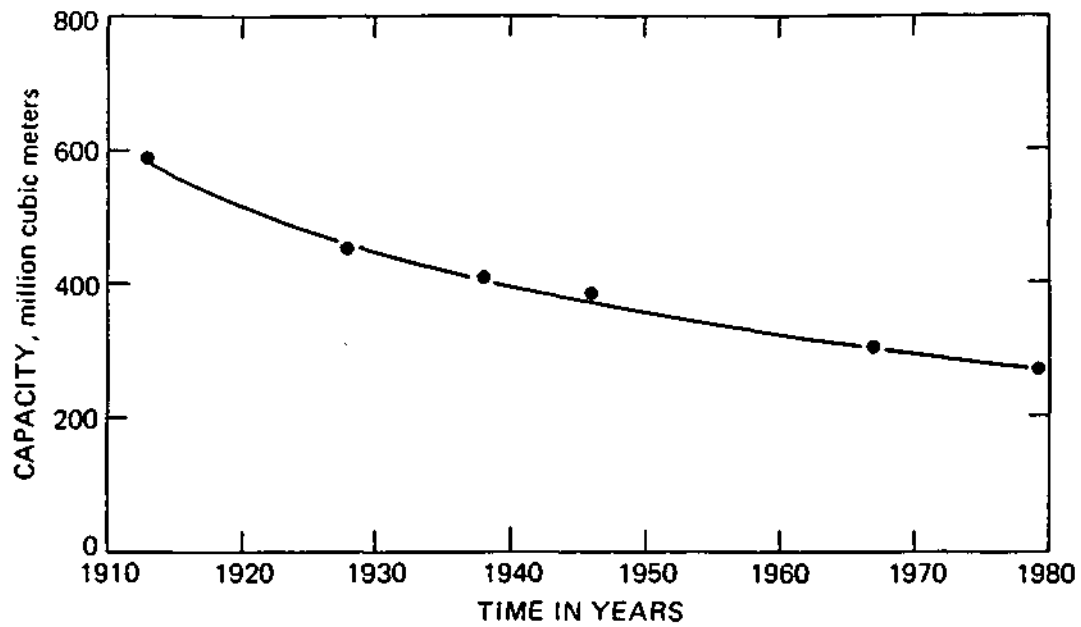


Figure 5. Changes in capacity of Pool 19 since 1913

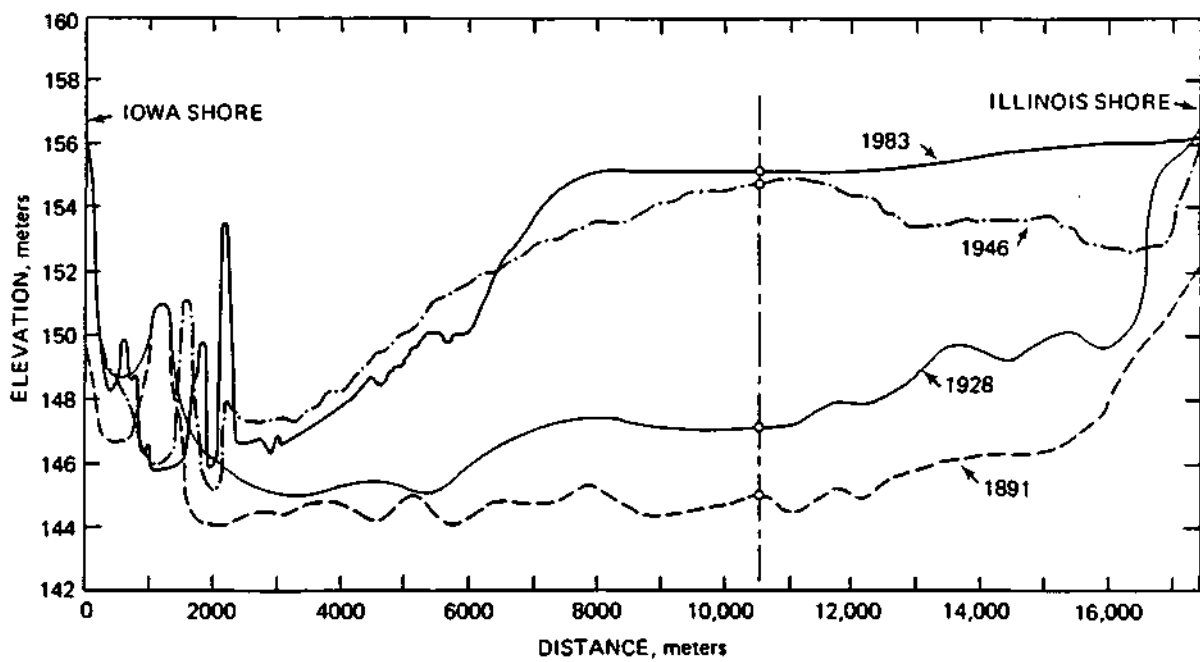


Figure 6. Variation of the Mississippi River cross section at river mile 364.8, just upstream of Lock and Dam 19

shore about 5 km upstream of the dam. The navigation channel remains fairly clear of sediment deposition.

The sedimentation pattern upstream of the lock and dam can further be illustrated with a set of river cross sections given in figures 7 and 8. The locations of these cross sections are given in figure 1. An examination of these figures indicates that the deposition of sediment near the Illinois shore has extended up to river mile 366.6, and other data have shown that this massive bar extends close to river mile 367.3. Buildup of this bar from 1946 through 1984 is again demonstrated in figure 9.

Figure 9 shows a bed contour map of the river bed above Lock and Dam 19 made on the basis of 1946 sounding data, and a second contour map of the same area that is based on 1984 sounding data. A close examination of these two plots indicates that the areal extent of the bar has broadened over the last 30 years. Moreover, water is extremely shallow near the Illinois shore, and if left undisturbed this area will probably turn into a wetland with extensive development of macrophyte beds. It has been estimated that by the year 2030 to 2050, this area will probably become an island with terrestrial habitats (Bhowmik and Adams, 1986) and little or no water for boating, fishing, or other recreational uses.

Proposed Action by Local Citizens/State

The extensive sedimentation of the river near the Illinois shore led to the natural conclusion by local interested citizens that an attempt must be made to remove this massive sediment bar and restore this river to a state close to its original condition, or at least to develop and maintain a deep channel at this location. One of the suggestions that is being pursued actively is to initiate a scouring action of the deposited sediment by the increased velocity that will develop when some of the gates of the dam near the Illinois shores are kept open. It is hoped that this scouring of the sediment will maintain a deeper channel near the city of Hamilton. It should be noted here that scouring of the deposited sediment by sluicing is quite feasible. As a matter of fact, during the 1973 flood, most of the crest gates on Lock and Dam 19 were kept open to allow the passage of flood flows. During this event, the high velocity flow scoured and transported downstream almost one year's equivalent sediment load of the Mississippi River at this location (Bhowmik and Adams, 1986). Figure 4

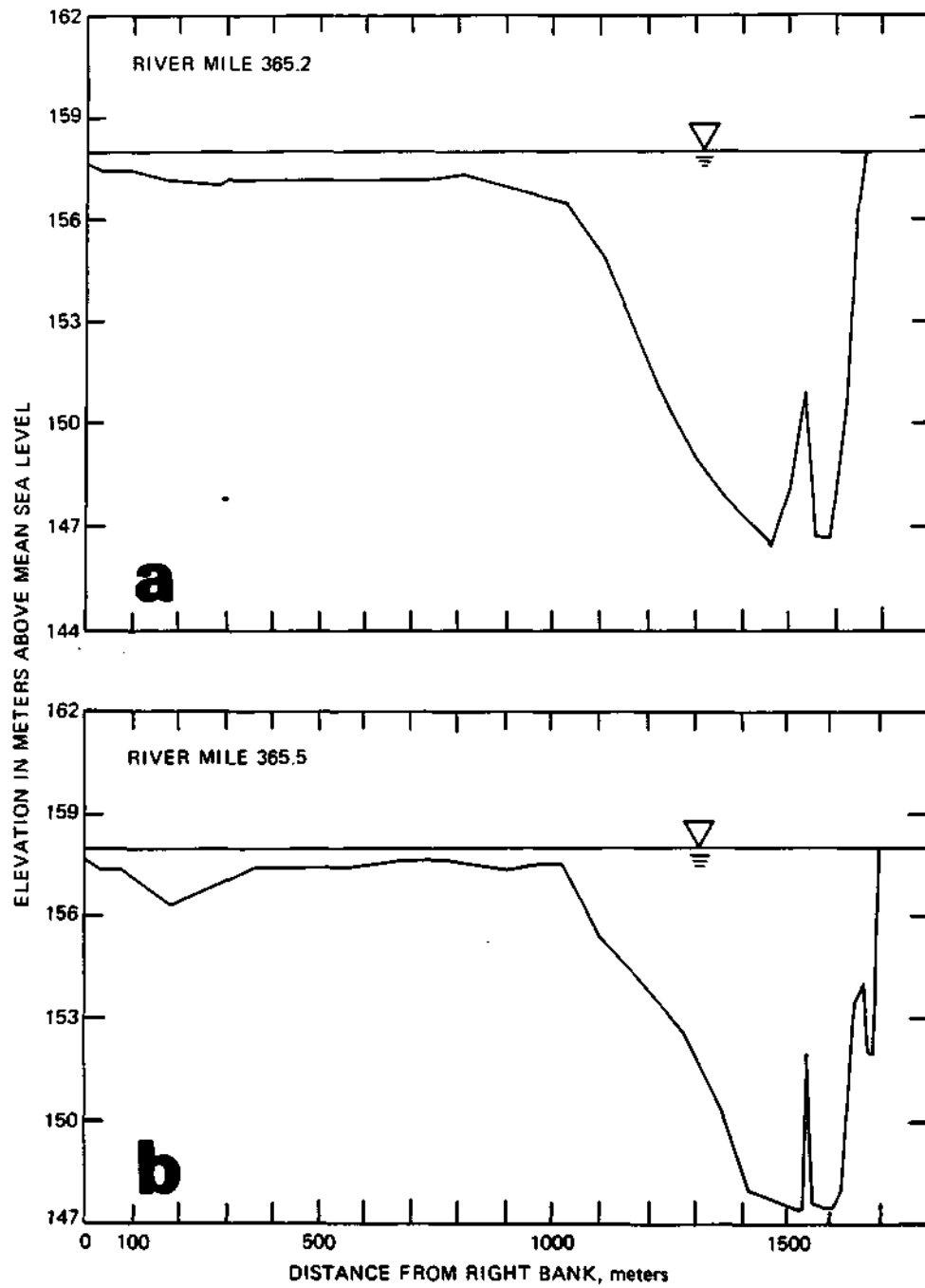


Figure 7. 1984 cross sections at a) river mile 365.2 and b) river mile 365.5

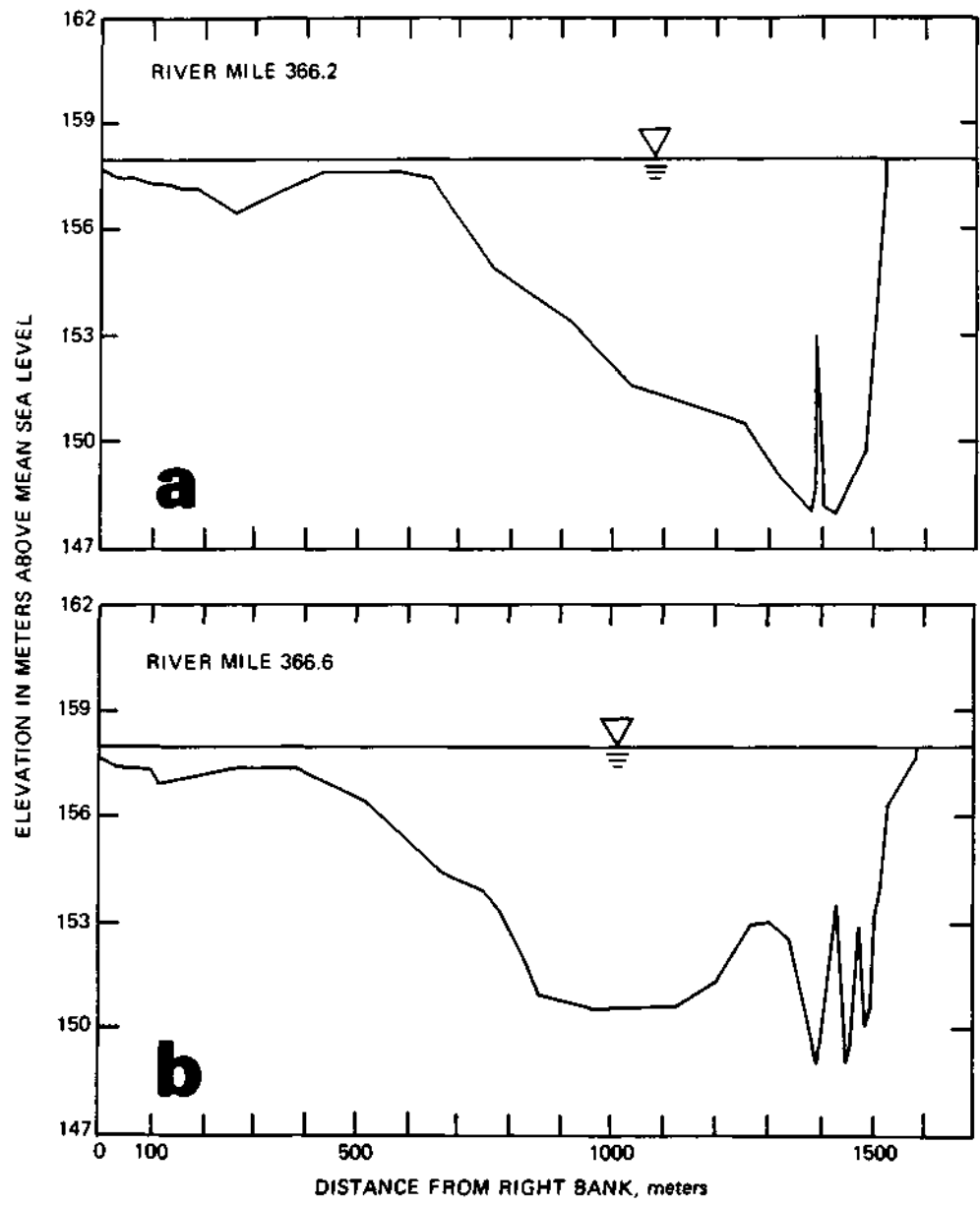


Figure 8. 1984 cross sections at a) river mile 266.2 and b) river mile 366.6

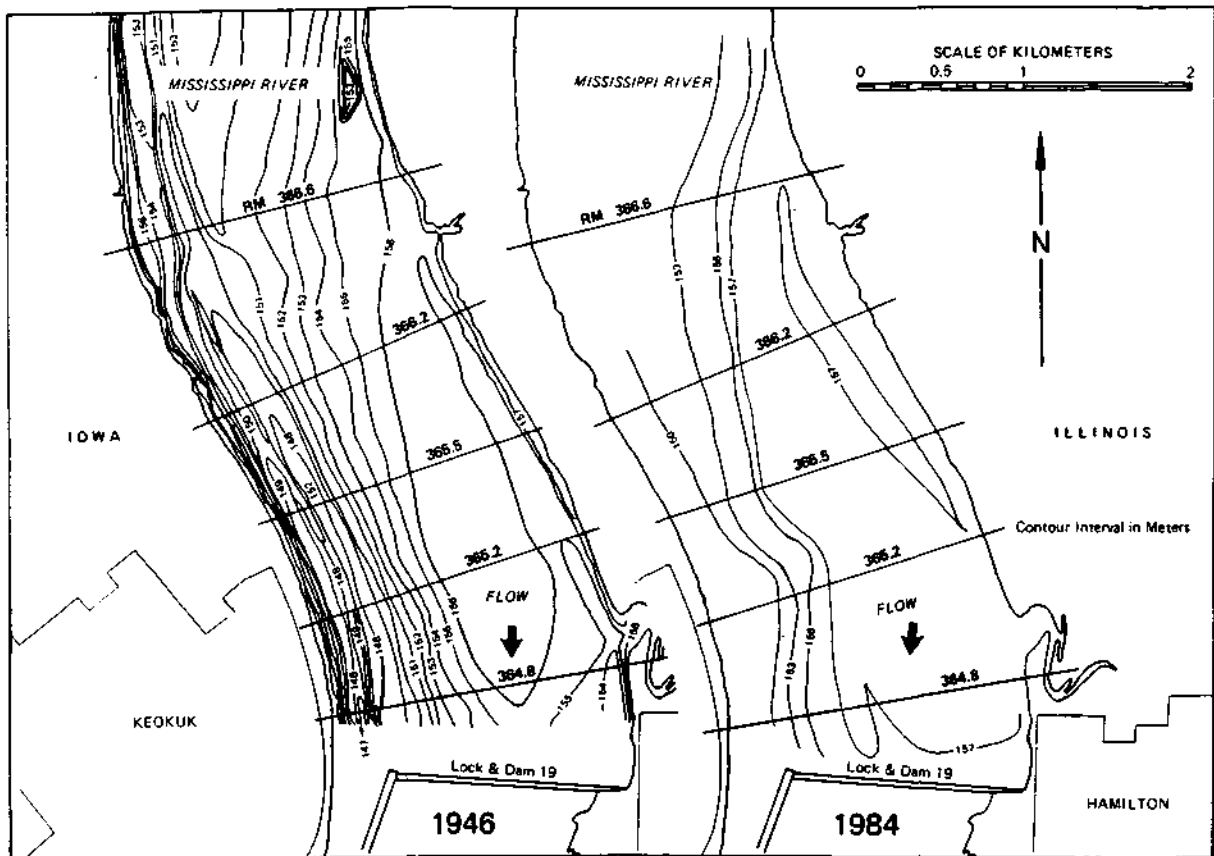


Figure 9. 1946 and 1984 bed contours of the Mississippi River above Look and Dam 19

also illustrates the effect of this scour during the 1973-1974 season. Therefore, with a proper design and plan, it is quite feasible to scour some of the deposited sediment from above the dam by opening the crest gates during high and median flows on the Mississippi River. Sluicing of the deposited sediment by opening gates or bottom sluices has been practiced in various parts of the world (USDA, 1942; Jiahua, 1960; Jiahua and Rujin, 1980; Parhami, 1986).

Knowledge of the hydraulics of flow of the Mississippi River and the sediment transport and sedimentation within a reservoir indicates that attempts can be made to determine if opening the gates will have the desirable impact of resuspending some of the deposited sediment. However, before such an attempt is made, a plan should be developed and implemented to evaluate the effectiveness of such a demonstration project.

Evaluation and Proposed Recommendations

It is recommended that a demonstration project be evaluated, with a follow-up report indicating the usefulness of such an operation. The evaluation will include an analysis of the existing data, collection and analyses of field data during the demonstration, and preparation of a report. An evaluation is essential in order to determine whether or not such an operation on a semi-permanent basis will have the desired effect of keeping a deeper channel open near the Illinois shore close to the city of Hamilton.

Data collection for such a project will include: bed elevation measurements at various cross sections before, during, and after the gates have been opened; suspended sediment load measurements at upstream and downstream sections during the demonstration project (to determine the net volume of sediment being scoured from above the dam); sediment analyses to determine particle size distribution and quality; and a determination of the discharges when the gates are opened.

On the basis of the analyses of the existing and collected data and also from an intimate knowledge of the hydraulics of flow and sediment transport characteristics of the Mississippi River, a set of recommendations will be made for implementation by the concerned agencies/authorities which will be useful in maintaining a deep channel near the city of Hamilton. It should be noted that such an alternative

solution may also be quite feasible for many lakes and reservoirs in Illinois where excessive sedimentation is a major problem.

Time and Cost: The project will last for about 12 months with a total initial cost of about \$45,000.

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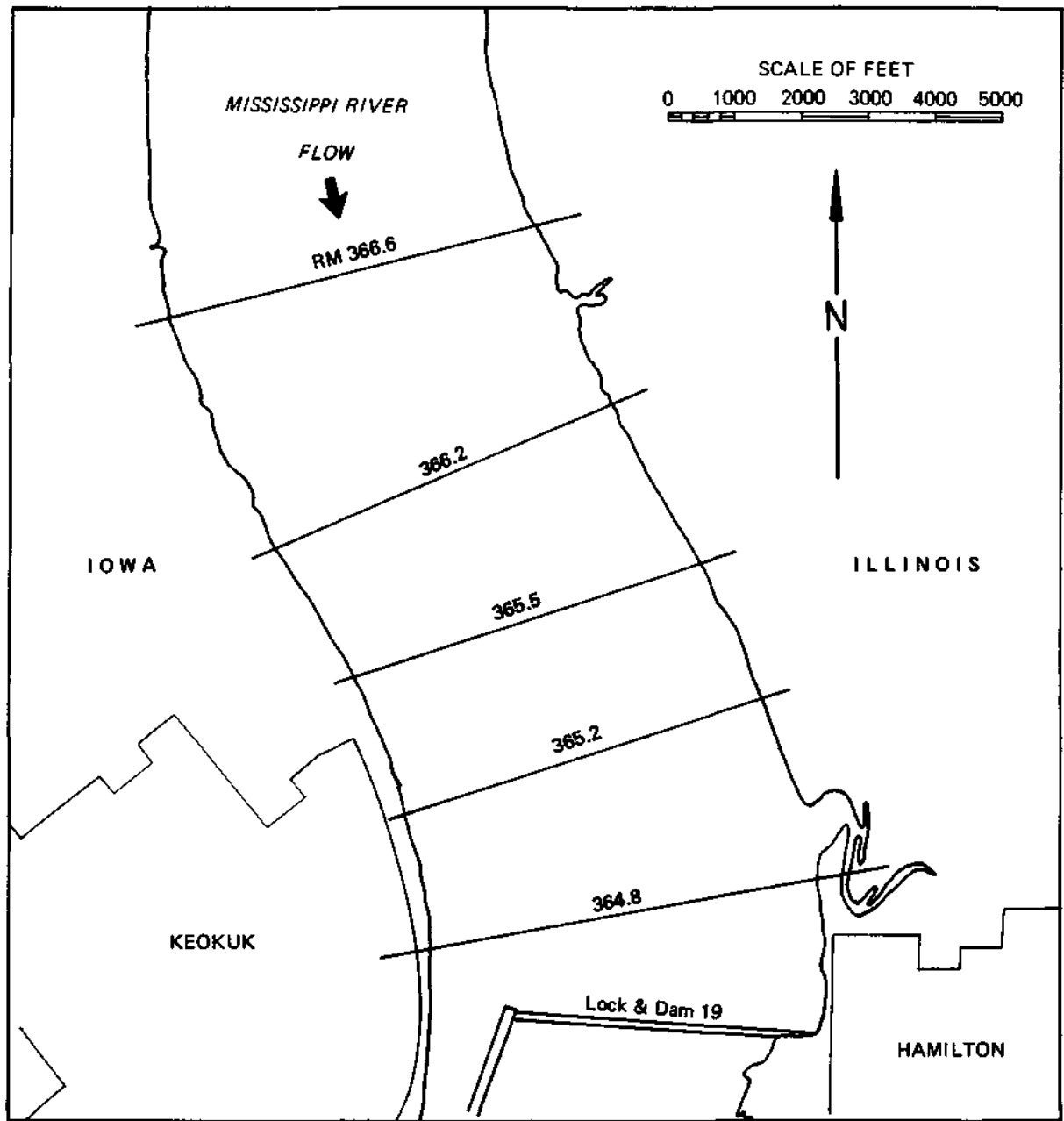


Figure 1. Lower portion of Pool 19 on the Mississippi River

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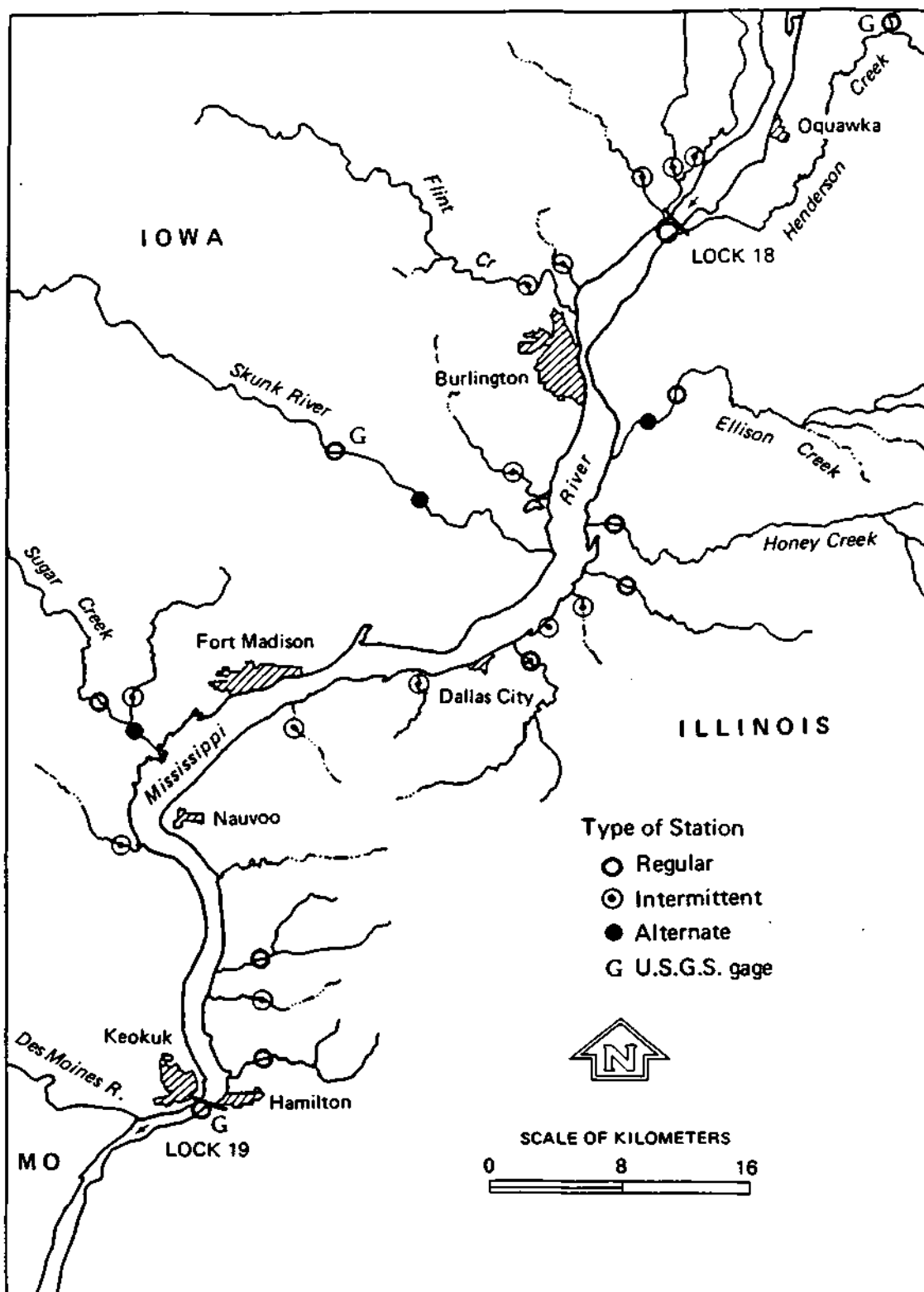


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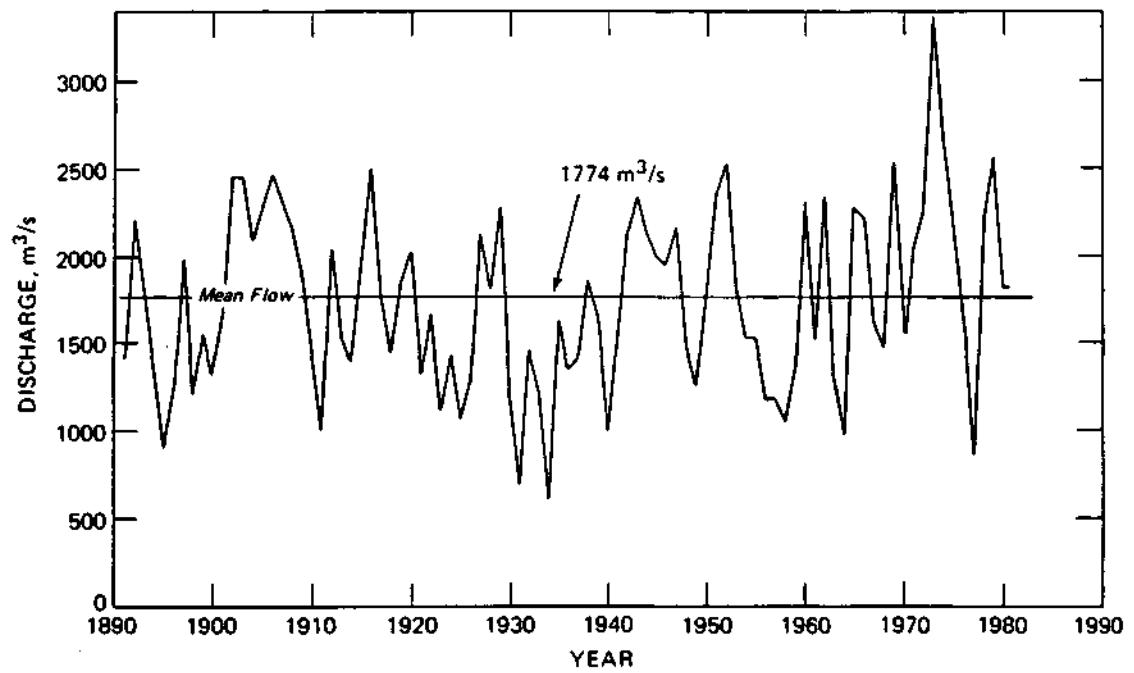


Figure 3. Discharge variability of the Mississippi River at Keokuk

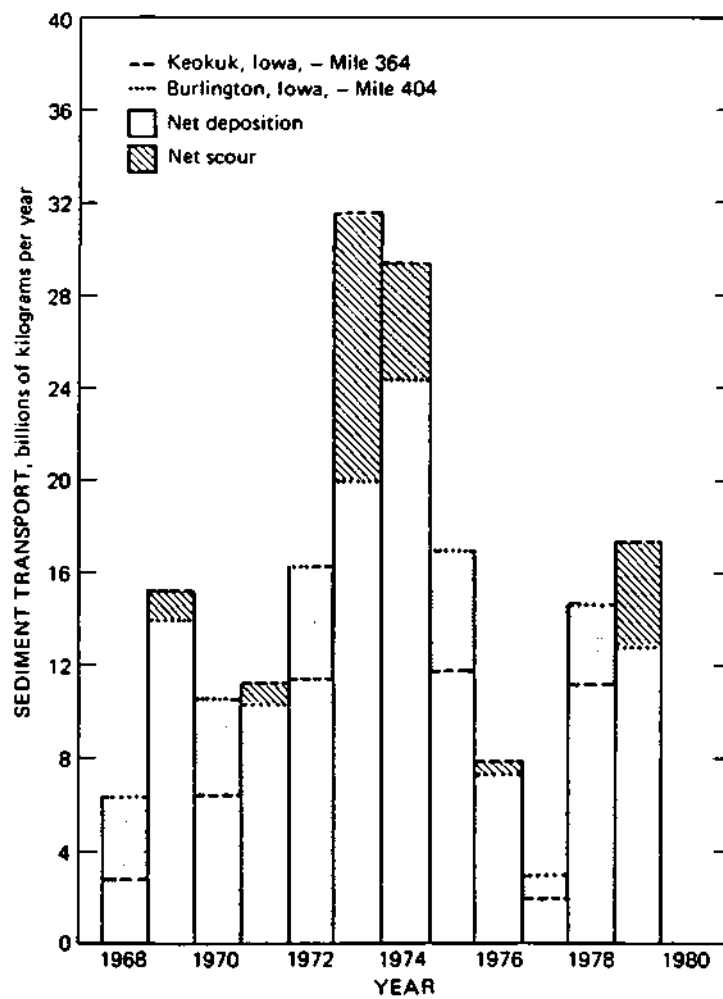


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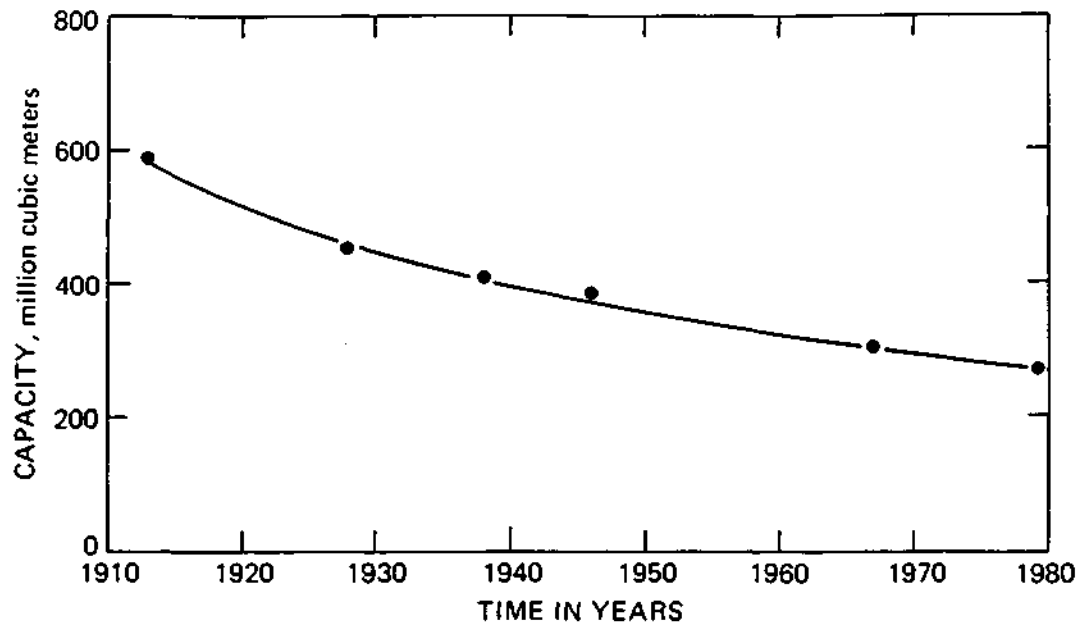


Figure 5. Changes in capacity of Pool 19 since 1913

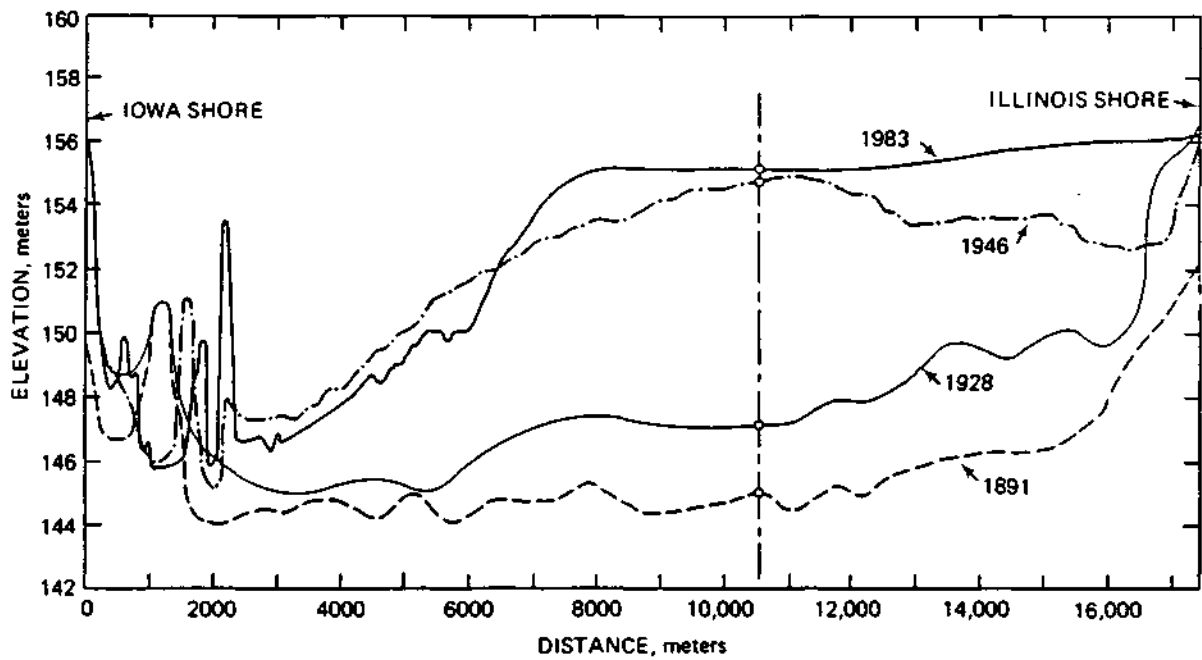


Figure 6. Variation of the Mississippi River cross section at river mile 364.8, just upstream of Lock and Dam 19

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Proposed Action by Local Citizens/State

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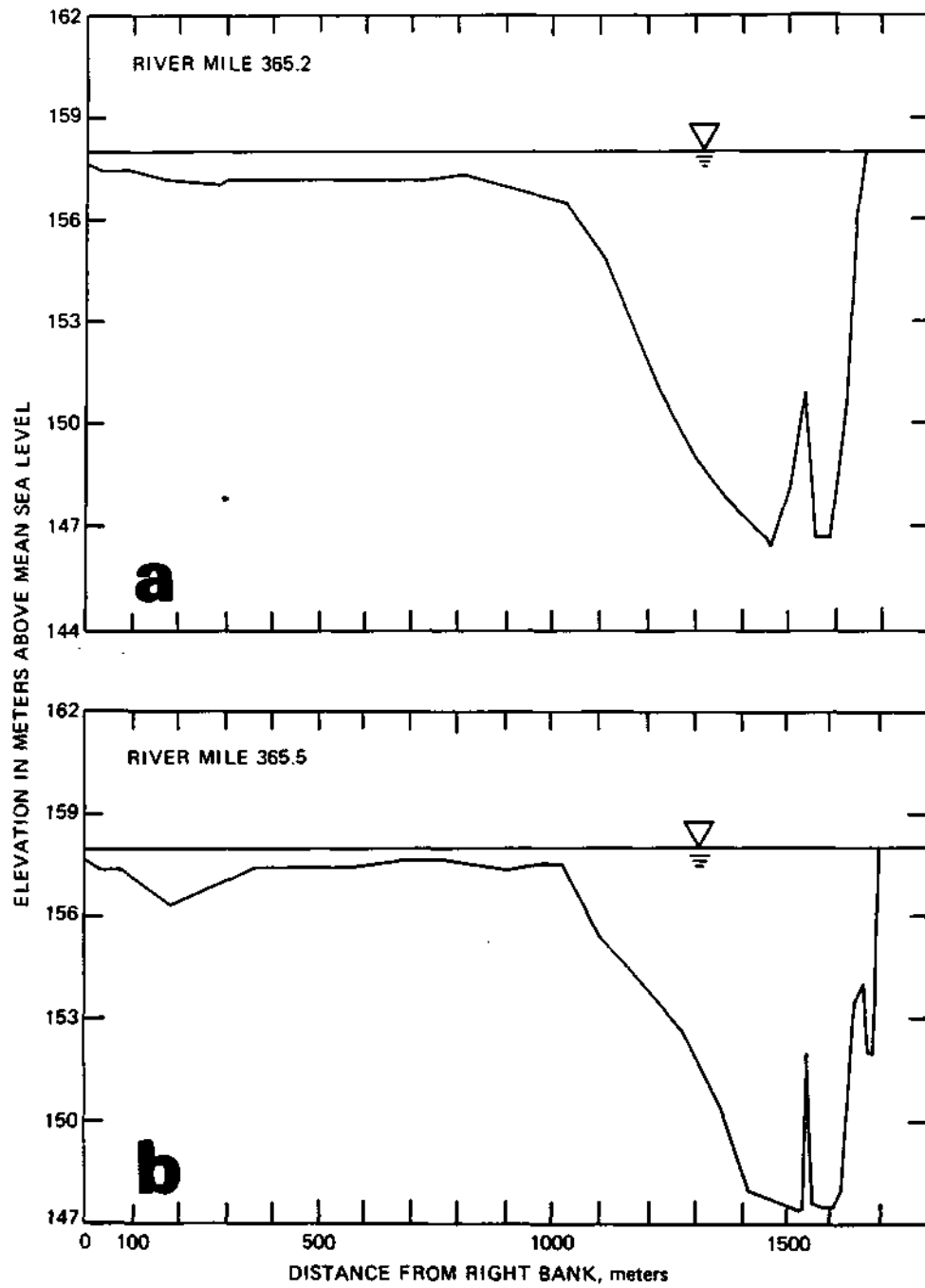


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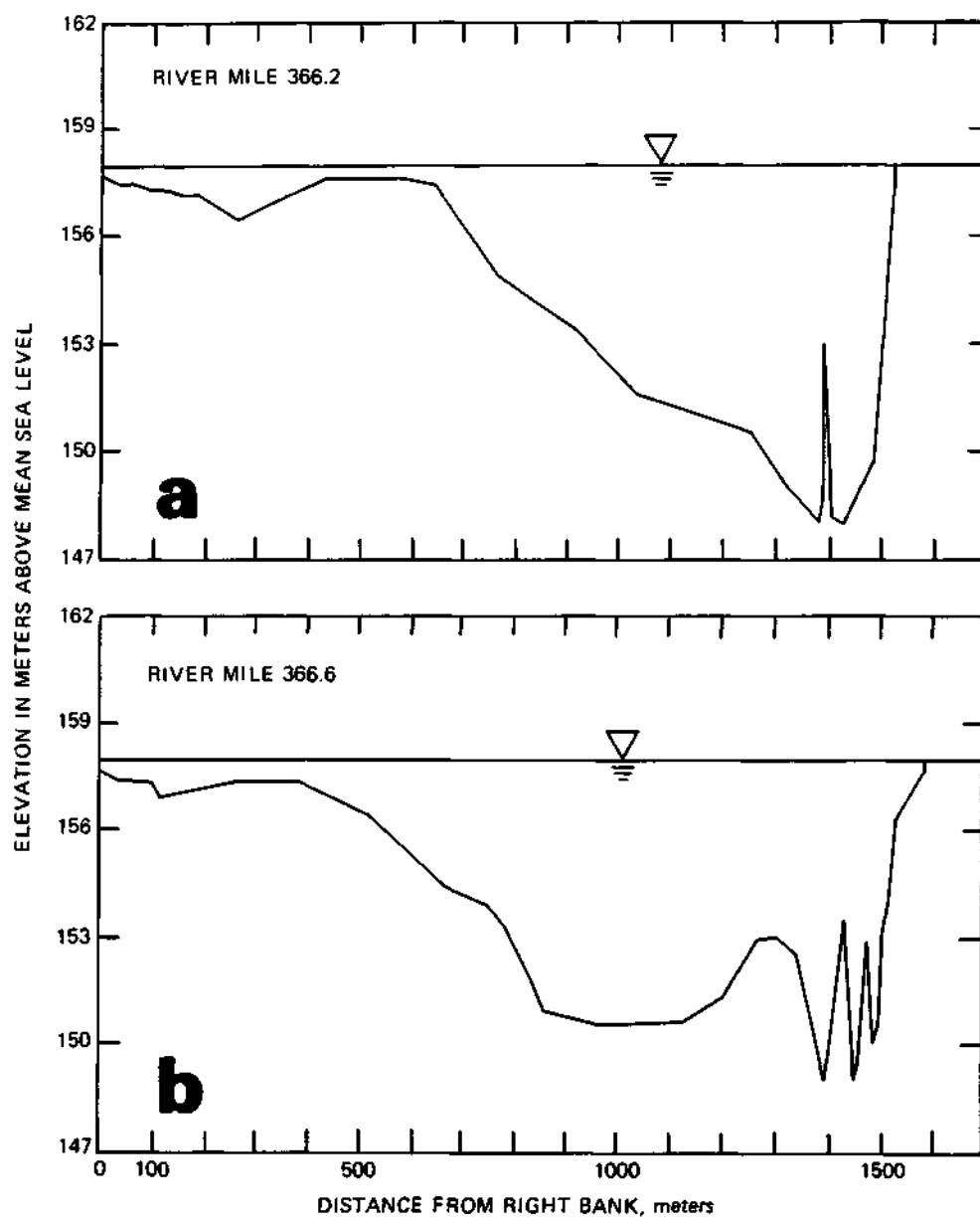


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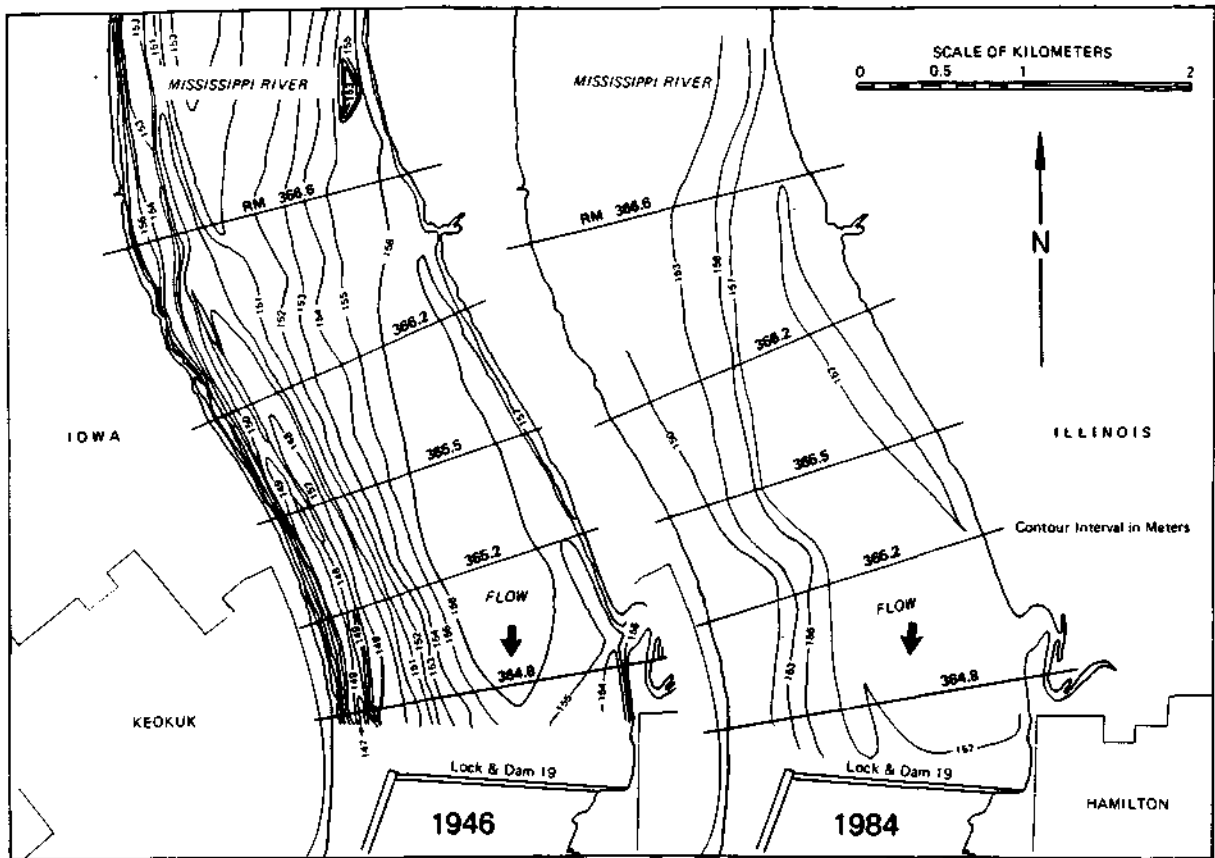


Figure 9. 1946 and 1984 bed contours of the Mississippi River above Lock and Dam 19

also illustrates the effect of this scour during the 1973-1974 season. Therefore, with a proper design and plan, it is quite feasible to scour some of the deposited sediment from above the dam by opening the crest gates during high and median flows on the Mississippi River. Sluicing of the deposited sediment by opening gates or bottom sluices has been practiced in various parts of the world (USDA, 1942; Jiahua, 1960; Jiahua and Rujin, 1980; Parhami, 1986).

Knowledge of the hydraulics of flow of the Mississippi River and the sediment transport and sedimentation within a reservoir indicates that attempts can be made to determine if opening the gates will have the desirable impact of resuspending some of the deposited sediment. However, before such an attempt is made, a plan should be developed and implemented to evaluate the effectiveness of such a demonstration project.

Evaluation and Proposed Recommendations

It is recommended that a demonstration project be evaluated, with a follow-up report indicating the usefulness of such an operation. The evaluation will include an analysis of the existing data, collection and analyses of field data during the demonstration, and preparation of a report. An evaluation is essential in order to determine whether or not such an operation on a semi-permanent basis will have the desired effect of keeping a deeper channel open near the Illinois shore close to the city of Hamilton.

Data collection for such a project will include: bed elevation measurements at various cross sections before, during, and after the gates have been opened; suspended sediment load measurements at upstream and downstream sections during the demonstration project (to determine the net volume of sediment being scoured from above the dam); sediment analyses to determine particle size distribution and quality; and a determination of the discharges when the gates are opened.

On the basis of the analyses of the existing and collected data and also from an intimate knowledge of the hydraulics of flow and sediment transport characteristics of the Mississippi River, a set of recommendations will be made for implementation by the concerned agencies/authorities which will be useful in maintaining a deep channel near the city of Hamilton. It should be noted that such an alternative

solution may also be quite feasible for many lakes and reservoirs in Illinois where excessive sedimentation is a major problem.

Time and Cost: The project will last for about 12 months with a total initial cost of about \$45,000.

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